CIT2016 – XII Congreso de Ingeniería del Transporte
València, Universitat Politècnica de València, 2016.
DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

Calibration of MATSim in the context of Natural Hazards in Liège (Belgium): Preliminary Results

Ismaïl Saadi
PhD candidate, University of Liège, Belgium

Ahmed Mustafa
PhD candidate, University of Liège, Belgium

Jacques Teller
Full Professor, University of Liège, Belgium

Mario Cools
Associate Professor, University of Liège, Belgium

ABSTRACT

In Belgium, river floods are among the most frequent natural disasters and they may cause important changes on travel demand. In this regard, we propose to set up a large scale scenario using MATSim for guarantying an accurate assessment of the river floods impact on the transportation systems. In terms of inputs, agent-based models require a base year population. In this context, a synthetic population with a respective set of attributes is generated as a key input. Afterwards, agents are assigned activity chains through an activity-based generation process. Finally, the synthetic population and the transportation network are integrated into the dynamic traffic assignment simulator, i.e. MATSim. With respect to data, households travel surveys are the main inputs for synthesizing the populations. Besides, a steady-state inundation map is integrated within MATSim for simulating river floods. To our knowledge, very few studies have focused on how river floods affect transportation systems. In this regard, this research will undoubtedly provide new insights in term of methodology and traffic pattern analysis under disruptions, especially with regard to spatial scale effects. The results indicate that at the municipality level, it is possible to capture the effects of disruptions on travel behavior. In this context, further disaggregation is needed in future studies for identifying to what extent results are sensitive to disaggregation. In addition, results also suggest that the target sub-population exposed to flood risk should be isolated from the rest of the travel demand to reach have more sensitive effects.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

1. INTRODUCTION

The assessment of the impact of river floods on the transportation system, including the network and the travel demand, is of great importance in the Meuse river Basin (Belgium) to mitigate flood risk. According to different studies (B. Dewals et al., 2015; B. J. Dewals et al., 2015), river flood risk is expected to increase in the coming decades along with higher intensities and damages. Furthermore, the changes in land-use patterns at catchment scale also influence the overall river flood risk as demonstrated by Mustafa et al. (2015; 2015). In this context, we assume that the transportation sector is also an amplifying factor of future flood risk in the Meuse basin. According to the predictions realized by Statistics Belgium, the population is expected to increase by 17% between 2013 and 2060. As a result of the population growth and the changes in travel behavior, the travel demand will inevitably increase in the future.

To ensure policy sensitive effects within the modelling framework and to capture the complex underlying interactions in the travel behavior of the travelers, we opt in this paper for an agent-based micro-simulation approach. In literature, various studies based on the agent-based paradigm are proposed to investigate the environmental impact of different policy scenarios (e.g. the emissions of air pollutant (Hülsmann et al., 2014)) using a fully integrated approach, or even the behavior of individuals in the context of large scale evacuation scenario (Lämmel et al., 2010).

On the basis of the framework developed by Saadi et al. (2014), we use MATSim for modeling the mobility of the travelers through the transportation network. MATSim has widely been used in different fields, and often integrated within other sub-modules to merge external phenomena and examine the effects on the travel demand and the network. MATSim can estimate time dependent traffic flows for each road segment of the network. The framework of MATSim includes a feedback loop, i.e. re-planning, such that each traveler is capable of optimizing its daily activity-travel patterns using a scoring function calibrated according to Charypar and Nagel (2005).

The agent-based micro-simulation approach is particularly interesting to assess the changes in traffic flows of the road segments which are directly situated in the vulnerable areas. In addition, the driver's dynamics can be captured more efficiently for each vehicle as well as rerouting.

Besides, the input in term of travel demand is partially based on the approach proposed by Saadi et al. (2016) for generating a full synthetic population and assigning activity sequences for individuals. Additional information related to activity locations and activity durations are derived from the activity-travel diaries of the Belgian National Household Travel Survey (Cornelis et al., 2012).

The main contribution of this paper is the calibration of MATSim in the context of natural hazards, i.e. river floods. To our knowledge, no studies really investigated the effects induced by river floods in urban areas. We will show that it is important to use highly disaggregate data to capture as much as possible the changes in travel behavior of the agents subjected to flood risk.

Furthermore, a key challenge is also to maintain a highly spatial resolution when it comes to integrate the agent-based micro-simulation with a detailed river flood map. In this

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

regard, the scenario is based on the results of a steady-state river flood map derived from Beckers et al. (2013) to identify which road segments are subjected to capacity mitigation.

An accurate analysis of the aspects that may influence the intensity of eventual flood risk in the future is absolutely necessary. In this context, the integrated agent-based micro-simulation model can be an efficient tool for urban and transport planners to prevent urban areas from eventual direct or higher order damages due to river floods. Such models are particularly suitable to establish some policy recommendations in terms of, e.g. extension of the transportation network, reorganization of the traffic flows within the vulnerable areas (catchment scale), land-use change, identification of the bottlenecks, etc.

2. DATA

The impact assessment is conducted for the Meuse river basin which crosses the Walloon Region. In the context of this study, we will mainly focus on the city of Liège. Regarding data preparation, we first prepare a full synthetic population for Liège using socio-demographics from the Belgian National Household Travel Survey (BELDAM) of 2010 and the marginal distributions of 2015 available within the online platform of Statistics Belgium.

Population synthesis is performed by using a standard IPF approach as presented in Beckman et al. (1996). A set of four attributes (age, residential location, socio-professional status and gender) has been selected from the BELDAM survey to build the micro-sample (seed). In addition, the aggregate marginal distributions at the national level have been extracted from Statistics Belgium and will be used as controls by the IPF algorithm. The basic statistics about the synthesized variables are presented in Table 1.

The BELDAM survey contains 2 data-sets:

- a set detailed socio-demographics and additional characteristics about each individual;
- a set of recorded trips related to the above individuals.

Based on the socio-demographics and the residential location, each individual has been assigned activity sequences, i.e. succession of activities and trips. In this way, the built travel demand reached a set of 12,924 individuals with additional detailed information about activity locations (at municipality level) and activity end times. With respect to the activity locations, it was not possible to reach higher level of disaggregation because the trip origins and destinations are described using postal codes. In this context, activity locations are randomly selected within each municipality according to the coordinate system EPSG: 31370 for Belgium.

In 2015, the population of Liège accounts for around 1,094,791 individuals. In this regard, 25% of the individuals (12,924) have been extracted from the travel demand group built previously such that it represents +/- 1% of the real population. Note that the real size is never synthesized in MATSim otherwise the run-time would be too high. However we show that the results should be interpreted carefully because it may have an influence on the traffic flows and the travel times.

The transportation network can be derived from OpenStreetMap. After cleaning and adapting the network to the format accepted by MATSim, the two key inputs can be integrated into modelling framework for performing the simulations.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

Table 1 - Data description about the synthetic population produced by IPF

Variables	Statistics
Age	
Less than 15	11.38%
Between 15 and 25	10.63%
Between 25 and 45	23.79%
Between 45 and 65	31.75%
Between 65 and 85	18.63%
More than 85	3.81%
Residential location	88 municipalities
Socio-professional status	2: 17.08% - 3: 4.23% - 4: 6.55% - 5: 30.16% 6: 2.31% - 7: 7.00% - 8: 2.13% - 9: 21.54% 10: 2.99% - 11: 0.89% - 12: 4.61% - 13: 0.05% - 14: 0.49%
Gender	Male: 46.92% - Female: 53.08%

3. MODEL CALIBRATION

As briefly mentioned, the simulation network is delimited for Liège area. However, we do not model the entire travel demand of Belgium as we consider that disruptions within Meuse river basin will not have significant impact on the travel behavior of the individuals living too far from the disrupted zones. In contrast, we suppose that the travelers coming from outside the study area toward Liège, i.e. to work or perform any kinds of activities are not modelled.

In addition, we do not keep the entire network of Belgium. In this regard, people living in Liège and working in other areas, e.g. Brussels, Anvers, Namur, and Hasselt are not represented.

With respect to the individuals working in Luxembourg, Germany and the Netherlands, we did not consider them completely within the modelling framework because (i) their contribution regarding the overall traffic demand is not that important and (ii) additional data preparation are necessary to integrate the networks of Belgium and the neighboring countries.

Regarding the network, each road segment is represented by a link characterized by three main parameters:

- the free flow speed;
- the length;
- the capacity.

In MATSim, the routing module determines the shortest path based on the link travel times. In this context, the router module can find the path from one node to another on the basis of a weighted graph.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

The simulated network results in a set of 24,372 nodes and 55,959 unidirectional links. Regarding model settings, the parameter scale is set equal to 1%. All the results are estimated for 50 iterations.

Figure 1 presents an overview of the inundation extent (light blue) for an extreme scenario. We can observe that the interconnections between both sides of Meuse River are disturbed.

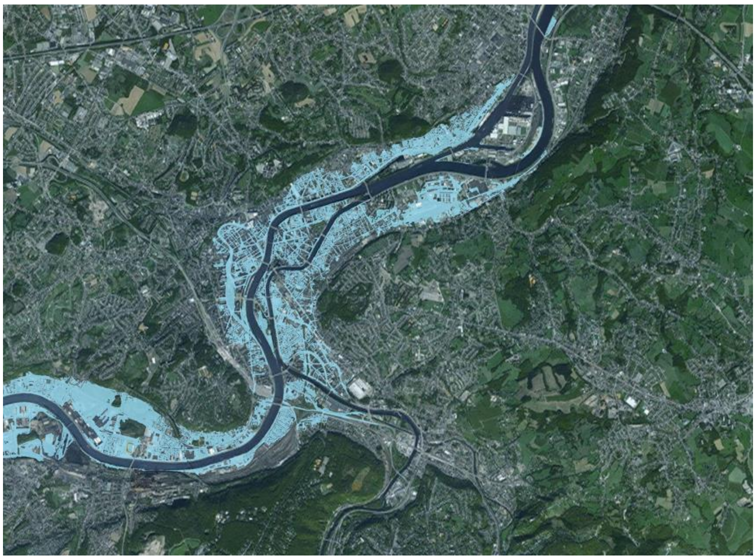

Figure 1 - Inundation extent within the Liège Area

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

4. RESULTS

The following results present an analysis where the number of trips is classified according to categorized travel times. The categorization is structured as follows (Table 1).

Table 2 - Travel time categorization

Category	1	2	3	4	5	6	7	8	9
Travel time interval [mins]	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40+

In Figure 2, we can observe that the commuting and daily-shopping trips are the most important in terms of occurrence while the travel times are quite small for commuters (between 5 and 10 mins) and relatively higher for daily-shopping trips (until 35 mins). Reciprocally, the trip pattern d-h (Figure 3) (shopping activity to home) is also significantly present for all the ranges of trip durations. In addition, Figure 3 reveals that 25% of the commuters perform additional trips after work before going back home. In this context, the number of trips patterns w-h is relatively smaller than h-w.

Note that these results should be considered carefully as in reality travel times are more important for the different patterns. For example, according to the reference dataset BELDAM, the mean travel time for the trips with work purpose are around 22 mins against 29.6 mins when commuters go back home. This comparison shows that further improvements need to be done to make the scenario more realistic.

In fact, we are modelling a sample of the population (1%). In this way, other rescaling approaches should be applied to reach more realistic travel times. The scaling factor that is used by MATSim refers generally to the comparison between observed and simulated traffic counts. Indeed, the traffic flows within the different road-segments are corrected with the scaling factor, i.e. multiplication by 100 in our case, so that the traffic flows are compared on the same basis. However, they do not affect the classification of the trips according to the durations, thus, leading to lower travel times.

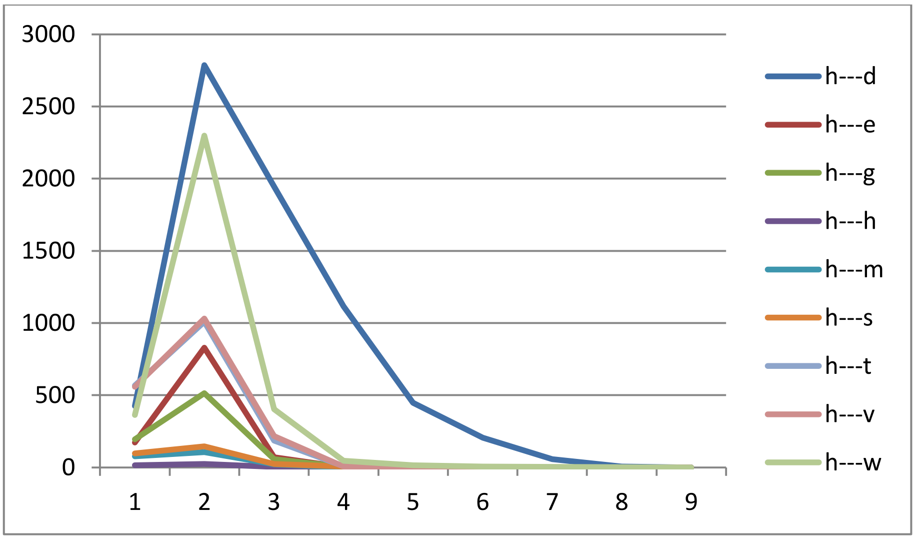

Figure 2 - Trip durations from home to other activities

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

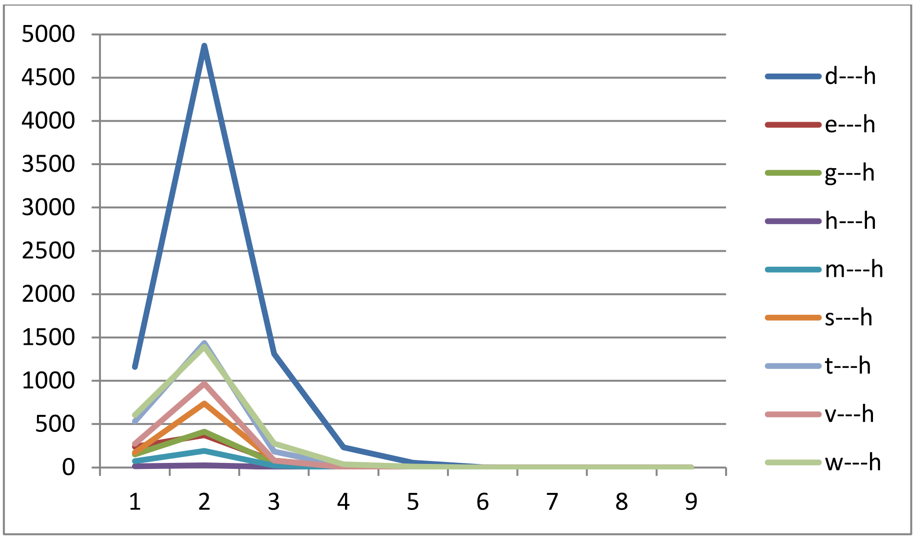

Figure 3 - Trip durations from any activity toward home

The results in Figures 4 and 5 represent respectively the average number of trips with respect to 9 travel time categories (see Table 2). In particular, Figure 4 presents the comparison between the averaged probability density function of the standard scenario (without river floods) and the one that includes river floods. In parallel, Figure 5 presents the results from the cumulative distribution perspective.

Results indicate that, for the city of Liège, the overall average trip duration is around 7.73 mins when considering normal traffic conditions without disruptions. In contrast, in presence of flooded areas, the average travel time increases by 1.55% to reach 7.85 mins.

In Figure 4, we can observe that an important amount of trips is performed in less than 10 mins then the distribution decreases significantly explaining in this way an average travel time around 7.5. Most of trips are concentrated within the first two intervals. The standard deviation follows approximately the same trend than that for the average number of trips.

Although the model is calibrated at the municipality level, the differences in the average number of trips within travel time categories are captured between the standard and the flooded scenarios. In this regard, we can conclude that the model is sensitive to small variations in the supply side (i.e. network) enabling changes in travel times (reclassification of the trips).

In addition, Figure 4 shows that the difference between the scenarios is positive at the beginning then it turns into negative difference. In means that part of the trips are reclassified because they increased in travel times because of the river floods. The travelers need to find longer paths to meet their activity needs.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

CIT2016 – XII Congreso de Ingeniería del Transporte
València, Universitat Politècnica de València, 2016.
DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

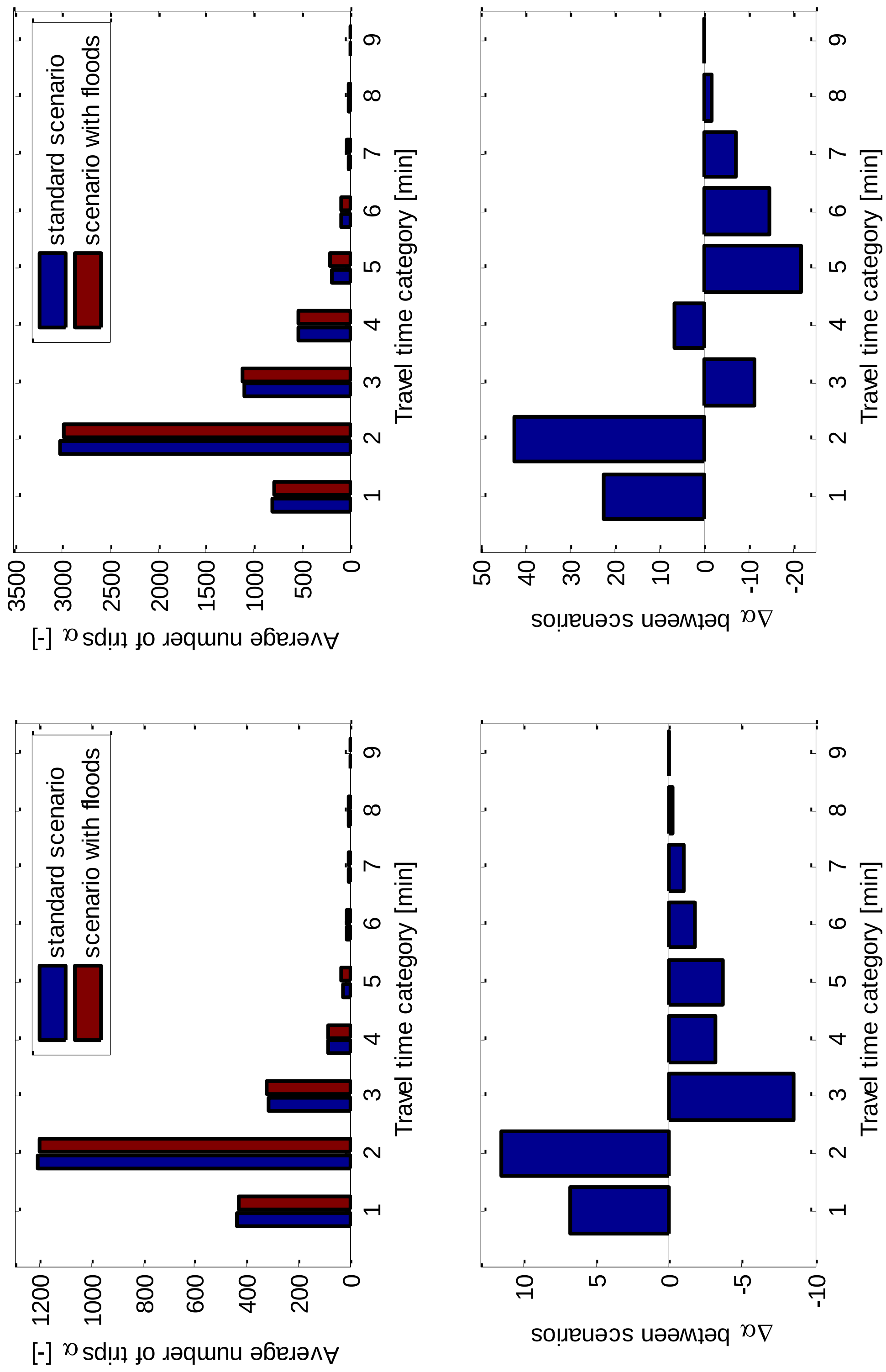

Figure 4 - Mean and Std.Dev. of the number of trips according to travel time category

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

CIT2016 – XII Congreso de Ingeniería del Transporte
València, Universitat Politècnica de València, 2016.
DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

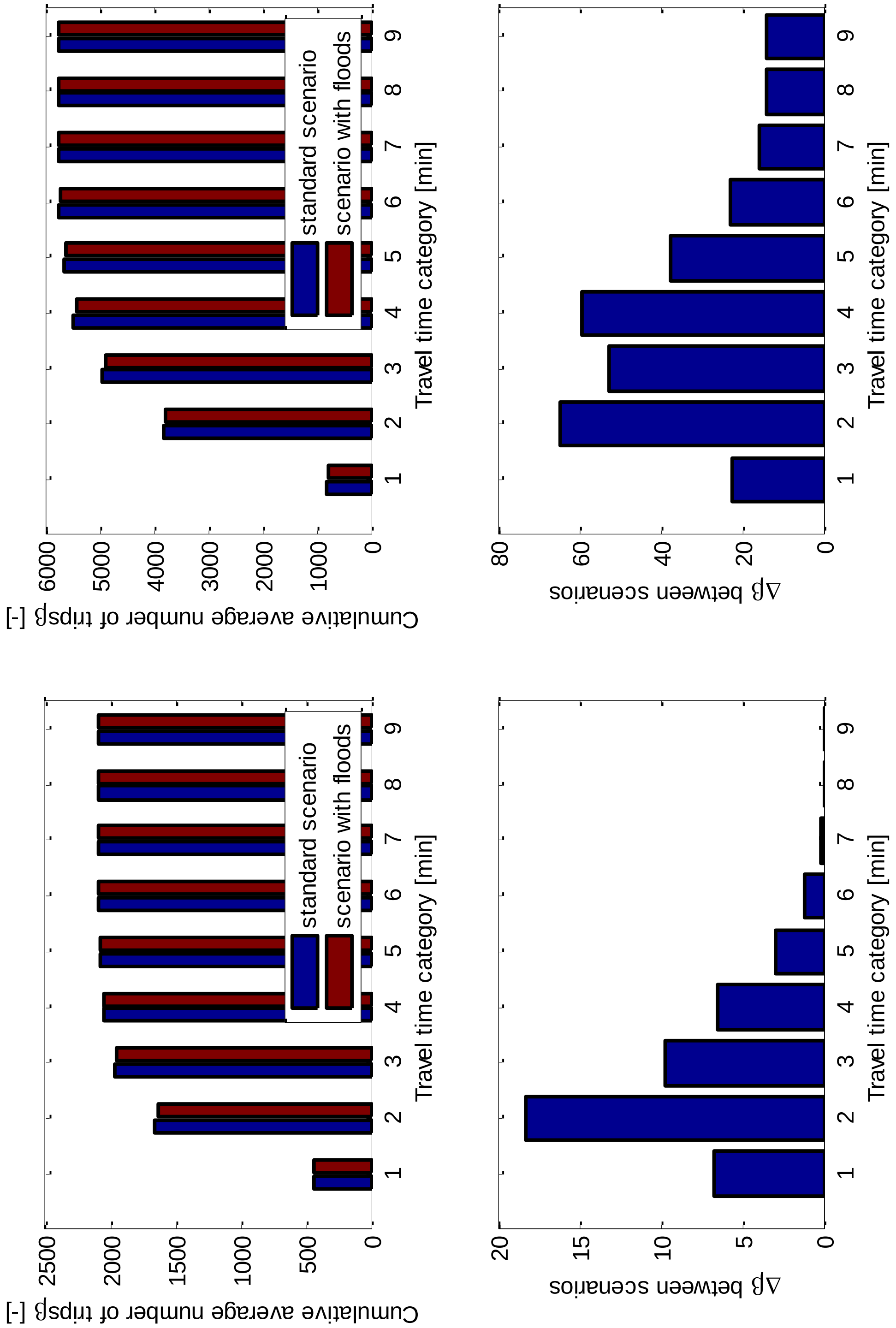

Figure 5 - Cumulative Mean and Std.Dev. of the number of trips according to travel time category

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

5. DISCUSSION AND CONCLUSION

In this paper, a large scale scenario has been calibrated using an agent-based micro-simulation approach for the city of Liège, in Belgium. After synthesizing the population for the selected socio-demographics and the residential locations using IPF, resulting activity chains stemming from the BELDAM survey have been assigned to each individual. In this context, the travel demand can be integrated as input within MATSim. In parallel, the transportation network of Liège area (southeastern Belgium) has been derived from OpenStreetMap (OSM). The two inputs are sufficient for simulating the mobility of the individuals living in Liège. To maintain a good trade-off between run-time and simulation error, a population sample of 1% has been built as proceeded in other studies (Hülsmann et al., 2014; Lämmel et al., 2010b; Novosel et al., 2015).

The main concluding remark that can be stated is that the municipality level is acceptable to capture the changes in travel behavior due to river floods. However, an analysis at a finer scale is necessary. Further improvements are needed to increase the reliability and the accuracy of the simulations. In this paper, we proposed to establish some lines of thought on calibration and integration of disruptions.

Modeling procedure should be carried out at the statistical sectors to obtain higher sensitivity levels to river floods. Hence, the level of aggregation has a great influence on route choice and travel times. Also, only the population directly subjected to river floods effects should be modelled otherwise we cannot observe any differences in terms of travel times between the standard scenario and the disrupted one. In this regard, additional analysis (not included in this paper) confirmed that no effects are detected because of the lack of sensitivity.

Furthermore, we considered only car mode while public transport, i.e. bus, might be seriously impacted by flood risk. Indeed, various bus lines are situated within the inundated areas.

Additional attributes should be added to the synthetic individuals for a further disaggregated representation of the population. Moreover, the target sub-population of the individuals who are more likely subjected to changes in travel behavior is to be isolated from the rest of the population. This suggested procedure presents also the advantage to mitigate the run-time as a lower amount of agents is processed during the simulations.

6. REFERENCES

Beckers, A., Dewals, B., Erpicum, S., Dujardin, S., Detrembleur, S., Teller, J., Pirotton, M., Archambeau, P., 2013. Contribution of land use changes to future flood damage along the river Meuse in the Walloon region. Nat Hazards Earth Syst Sci 13, 2301–2318. doi:10.5194/nhess-13-2301-2013

Beckman, R.J., Baggerly, K.A., McKay, M.D., 1996. Creating synthetic baseline populations. Transp. Res. Part Policy Pract. 30, 415–429. doi:10.1016/0965-8564(96)00004-3

Charypar, D., Nagel, K., 2005. Generating complete all-day activity plans with genetic algorithms. Transportation 32, 369–397.

Cornelis, E., Hubert, M., Hunyen, P., Lebrun, K., Patriarche, G., De Witte, A., Creemers, L., Declercq, K., Janssens, D., Castaigne, M., Hollaert, L., Walle, F., 2012. Belgian

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

DOI: http://dx.doi.org/10.4995/CIT2016.2016.4098

Daily Mobility (BELDAM): Enquête sur la mobilité quotidienne des belges. SPF Mobilité & Transports, Brussels.

Dewals, B., Erpicum, S., Archambeau, P., Pirotton, M., 2015. Modélisation mathématique des risques d'inondation dans le bassin liégeois suivant différents scénarios de changements climatiques et d'aménagement du territoire.

Dewals, B.J., Mustafa, A., Bruwier, M., Peltier, Y., Archambeau, P., Erpicum, S., Saadi, I., Orban, P., Dassargues, A., Teller, J., Pirotton, M., 2015. Landuse change and future flood risk: an integrated and multi-scale approach. E-Proc. 36th IAHR World Congr.

Hülsmann, F., Gerike, R., Ketzel, M., 2014. Modelling traffic and air pollution in an integrated approach – the case of Munich. Urban Clim., Source apportionment and modelling of urban air pollution 10, Part 4, 732–744. doi:10.1016/j.uclim.2014.01.001

Lämmel, G., Grether, D., Nagel, K., 2010a. The representation and implementation of time-dependent inundation in large-scale microscopic evacuation simulations. Transp. Res. Part C Emerg. Technol., Information/Communication Technologies and Travel Behaviour Agents in Traffic and Transportation 18, 84–98. doi:10.1016/j.trc.2009.04.020

Lämmel, G., Grether, D., Nagel, K., 2010b. The representation and implementation of time-dependent inundation in large-scale microscopic evacuation simulations. Transp. Res. Part C Emerg. Technol., Information/Communication Technologies and Travel Behaviour Agents in Traffic and Transportation 18, 84–98. doi:10.1016/j.trc.2009.04.020

Mustafa, A.M., Cools, M., Saadi, I., Teller, J., 2015. Urban Development as a Continuum: A Multinomial Logistic Regression Approach, in: Gervasi, O., Murgante, B., Misra, S., Gavrilova, M.L., Rocha, A.M.A.C., Torre, C., Taniar, D., Apduhan, B.O. (Eds.), Computational Science and Its Applications -- ICCSA 2015, Lecture Notes in Computer Science. Springer International Publishing, pp. 729–744.

Mustafa, A., Saadi, I., Cools, M., Teller, J., 2015. Modelling Uncertainties in Long-Term Predictions of Urban Growth: A Coupled Cellular Automata and Agent-Based Approach, in: Proceedings of the 14th International Conference on Computers in Urban Planning and Urban Management. Massachusetts Institute of Technology, Cambridge, MA, pp. 1–18.

Novosel, T., Perković, L., Ban, M., Keko, H., Pukšec, T., Krajačić, G., Duić, N., 2015. Agent based modelling and energy planning – Utilization of MATSim for transport energy demand modelling. Energy, Sustainable Development of Energy, Water and Environment Systems 92, Part 3, 466–475. doi:10.1016/j.energy.2015.05.091

Saadi, I., Eftekhar, H., Mustafa, A., Teller, J., Cools, M., 2014. An agent-based micro-simulation framework to assess the impact of river floods on transportation systems: implementation trajectory for an assessment in the Brussels metropolitan area. Proc. 2nd Int. Conf. Traffic Transp. Eng. 489–495.

Saadi, I., Mustafa, A., Teller, J., Cools, M., 2016. An Integrated Framework for Forecasting Travel Behavior Using Markov Chain Monte-Carlo Simulation and Profile Hidden Markov Models. Presented at the Transportation Research Board 95th Annual Meeting.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).